UM10791

SSL5021BDB1205 120 V 6 W candle form non-isolated buck LED driver demo board

Rev. 1 — 3 November 2014 **User manual**

Document information

Info	Content
Keywords	SSL5021BDB1205, SSL5021BTS, LED driver, non-isolated buck topology, candle applications, TSOP6 package
Abstract	This user manual describes the performance, technical data, and the connection of the SSL5021BDB1205 demo board, using non-isolated buck topology. The SSL5021BTS is an NXP Semiconductors driver IC in a TSOP6 package. It is intended to provide a low-cost, small form factor LED driver design. This SSL5021BDB1205 demo board is designed for candle-form applications. It operates at 120 V (AC), with an output voltage approximately 54 V.

Revision history

Rev	Date	Description
v.1	20141103	first issue

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1. Introduction

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Lethal voltage and fire ignition hazard

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This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

This user manual describes the operation of the SSL5021BDB1205 demo board featuring LED driver SSL5021BTS in a 120 V/6 W non-isolated application.

The SSL5021BDB1205 demo board is designed for driving LED loads from 40 V to 60 V with a nominal value of 55 V.

The PCB dimensions are compatible with candle applications.

The SSL5021BDB1205 demo board provides a simple and effective solution with a low output current ripple and high efficiency for Solid-State Lighting (SSL) applications.

1.1 Features

- Candle-form application
- Open/short LED string protection
- OverCurrent Protection (OCP)
- OverTemperature Protection (OTP)
- Efficiency > 88 % at 120 V (AC) input
- Compliant with IEC61000-3-2 harmonic standard
- Compliant with EN55015 conducted EMI

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2. Safety warning

The demo board input is connected to the mains voltage. Avoid touching the board while it is connected to the mains voltage and when it is in operation. An isolated housing is obligatory when used in uncontrolled, non-laboratory environments. Galvanic isolation from the mains phase using a fixed or variable transformer is always recommended. Figure 1 shows the symbols on how to recognize these devices.

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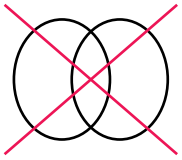
a. Isolated



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b. Not isolated

Fig 1. Isolation symbols

3. Specifications

Table 1 lists the specification of the SSL5021BDB1205 demo board.

Table 1. SSL5021BDB1205 specifications

Symbol	Parameter	Value
V_{mains}	AC mains supply voltage	120 V (AC); ±10 %
P_{out}	output power	6 W
V_{LED}	output voltage	40 V to 60 V (54 V optimum)
I_{LED}	output current	93 mA
I_{ripple}	output current ripple at 120 Hz	< 3 %
$\Delta I_{LED(Vmains)}/I_{LED(nom)}$	line regulation	1.0 % at V_{mains} = 90 V to 150 V
$\Delta I_{LED(VLED)}/I_{LED(nom)}$	load regulation	0.7 % at V_{LED}, ±10 %
η	efficiency	89 %; at 120 V (AC)/–60 Hz
PF	power factor	>0.55 at 120 V (AC)/–60 Hz
T_{oper}	operating temperature	–40 °C to +105 °C
	board dimensions	60 mm × 40 mm
	conducted electrostatic Interference (EMI)	EN55015
	IEC61000-3-2	Class D (for P_{in} < 25 W limit)

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Figure 2 shows the dimensions of the demo board.

Fig 2. SSL5021BDB1205 demo board dimensions

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4. Board photographs

a. Top view

b. Bottom view

Fig 3. SSL5021BDB1205 demo board photographs

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5. Board connections

The SSL5021BDB1205 demo board is optimized for a 120 V (AC)/−60 Hz supply. It is designed to work with multiple LEDs or an LED module.

Under the expected conditions, the output current is 93 mA when using an LED string with a 55 V forward voltage (V_F). The current can be adjusted using resistors R5. A 55 V LED voltage gives a good efficiency and line regulation at 120 V (AC).

K1 is the connection for the mains voltage. LED+ and LED− are the connections for the LED load. Figure 4 shows the connections.

Fig 4. SSL5021BDB1205 board connections

6. Functional description

6.1 Input filtering

Capacitors C1 and C3 and inductor L1 filter the switching current from the buck converter to the line. Capacitors C1 and C3 also provide a low-impedance path for the switching current. The value of C1 is selected to have no more than 30 % ripple on the bus voltage at −15 % of typical mains.

The input series resistance of 10 Ω and capacitor C1 together provide adequate protection against transient surge voltages. A footprint for an optional varistor RV1 is available on the board. To increase the immunity to the line surge, the input resistance is added (see Figure 11). Do not omit this resistor or lower its value.

6.2 Efficiency improvement for universal mains

The SSL5021BTS is supplied via start-up resistors R3 and R4. To keep the temperature low and retain ease of adjustment of the desired value, the power losses in these resistors are divided over the two resistors.

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For mains voltages up to 120 V (AC), a single 1206 size SMD resistor (R3) is sufficient. The maximum voltage and the power rating are not exceeded.

6.3 Open-load protection

The driver board is protected when the LED load is accidentally left open. The open-load protection is a non-latched protection. Two circuits set the open-load output voltage. One circuit sets the open-load output voltage when the IC does not operate because of a defect. The other circuit sets it when the IC is operating normally. In all cases, the output voltage must never exceed the rated DC voltage of the output capacitor.

Do not reconnect the LEDs directly after an open-load situation. The output capacitor is charged to a higher voltage than the total LED voltage, forcing an uncontrolled discharge current through the LEDs when connected. It can damage the LEDs permanently.

IC not operating:

The voltage divider consisting of resistors R3 and R4 sets the output voltage from the VCC pin of the IC to the GND pin of the IC and resistor R9.

$$V_{out} = \frac{(V_{drain} - 15) \cdot R9}{(R3 + R4 + R9)} \quad (1)$$

As a rule of thumb, limit resistor R9 to $\frac{(n \times 2.5\ V)}{225\ \mu A}$. In this way, the voltage is not sufficient to illuminate the LEDs (n is the number of LEDs in series at the output.

The non-operating output voltage must not be equal to or exceed the voltage set by the operating mode. It is good practice to set the level in non-operating mode 5 V to 10 V lower than in operating mode.

IC operating:

When the voltage in the non-operating mode is set to a safe level for the output capacitor, the voltage in the operating mode can be set. The DEMOVP pin detects overvoltage. It triggers when 4 consecutive high-frequency cycles at 1.8 V are detected at the DEMOVP pin. $V_{out} = 1.8 \cdot \frac{(R6 + R7 + R8)}{(R6)}$ sets the output voltage.

The output voltage must never exceed the rated DC voltage of the output capacitor.

6.4 External overtemperature protection and LED current foldback

Figure 11 shows the footprints of resistors R5 and R6. The purpose of these resistors is to provide thermal protection. To reduce light output when using output current foldback, the DEMOVP pin can be used as an input. Replace resistor R5 by a 470 Ω PTC resistor. Resistor R6 is kept at 5.1 kΩ. If the foldback option is not used, resistor R5 can be shorted and resistor R6 can be set to 5.6 kΩ.

When the foldback option is not used, efficiency can be further improved by increasing R6 to 12 kΩ. Do not use a value > 18 kΩ for resistor R6. If the value of resistor R6 is increased too much, the DEMOVP pin can cause false OVP triggering.

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6.5 LED current and sense resistors

To optimally profit from the excellent current stability of the SSL5021BTS, overtemperature 50 ppm MELF type resistors are chosen to sense the LED current. The output current stability range drops to 3 % compared to 7 % over the full temperature range for normal 200 ppm 1206 type resistors.

In most low-power, low-cost applications with LED currents < 150 mA, 200 ppm resistors are fine. $I_{LED(AV)}$ = 0.4 / R5 can adjust the average LED current. If the change is small (±10 %), changing the inductor is not required. At the lowest mains voltage, the maximum ON-time of Q1 must not exceed 15 μs.

When the sense resistor is operating at high temperatures, its power rating must be rated by a factor 2.

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7. Performance

V_{mains} = 85 V to 140 V (AC); t_{amb} = 25 °C; I_{LED} = 93 mA typical; V_{LED} = 55 V unless otherwise specified.

7.1 Efficiency

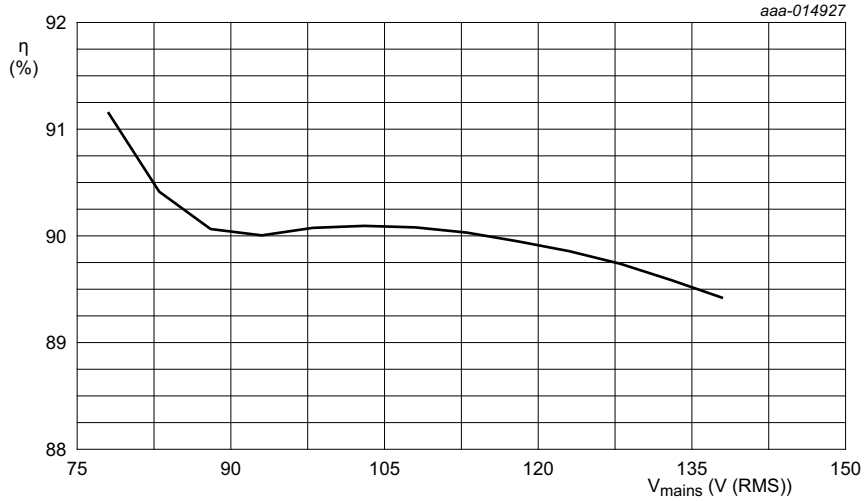

Fig 5. Efficiency as a function of mains voltage

7.2 Input power

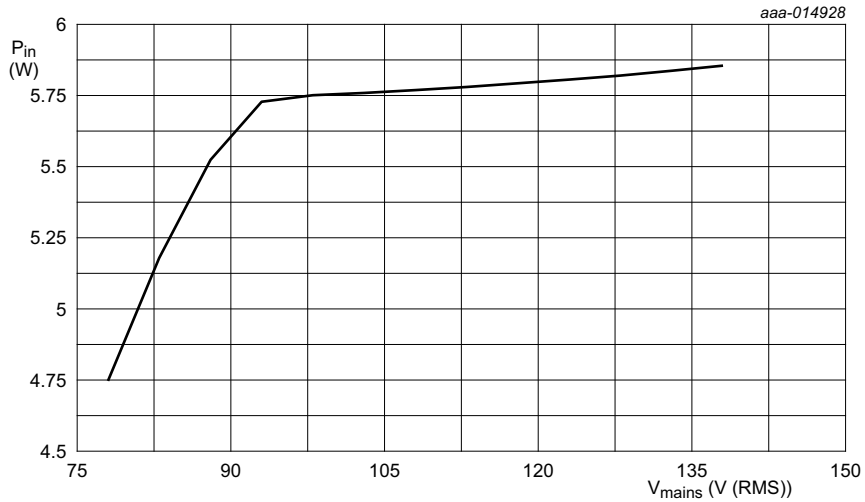

Fig 6. Power factor as a function of mains voltage

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7.3 Line regulation

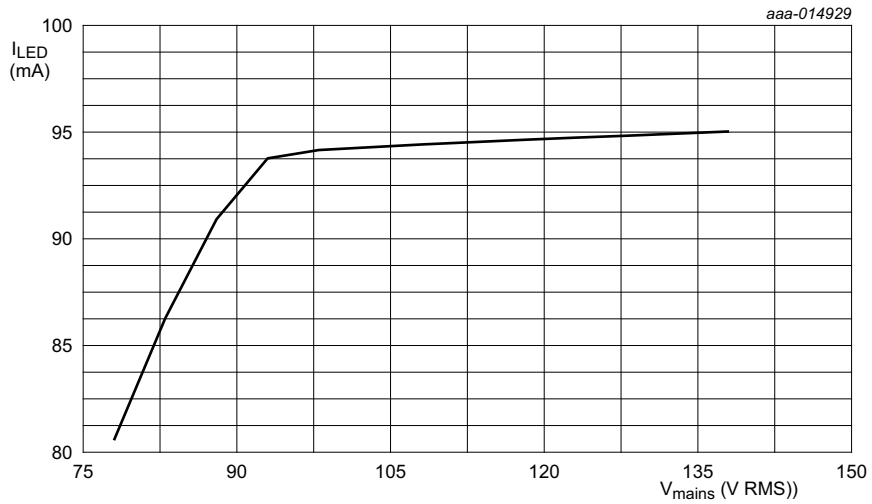
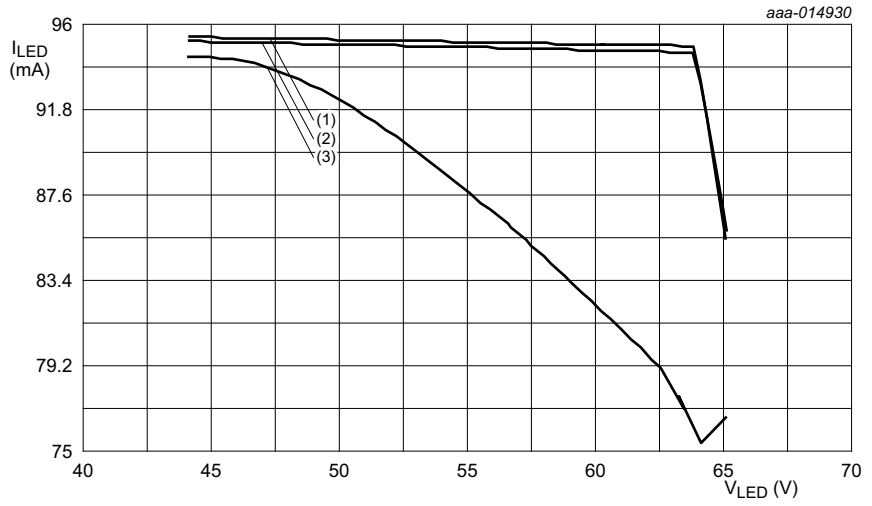


Fig 7. Output LED current as a function of mains voltage

7.4 Load regulation



(1) V_{mains} = 140 V (AC)

(2) V_{mains} = 120 V (AC)

(3) V_{mains} = 85 V (AC)

Fig 8. LED current as a function of LED voltage

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7.5 Output ripple

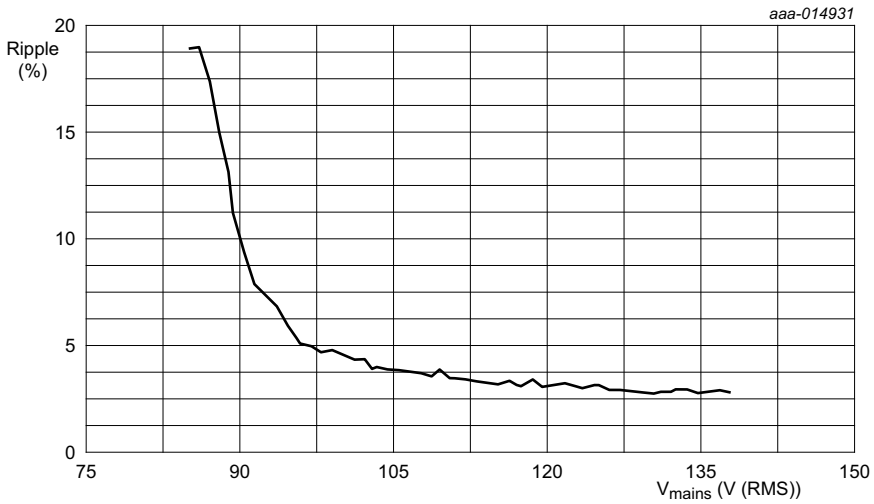

Fig 9. Output current ripple as a function of mains voltage

7.6 ElectroMagnetic Interference (EMI)

Figure 10 shows the conducted EMI result of the SSL5021BDB1205 demo board.

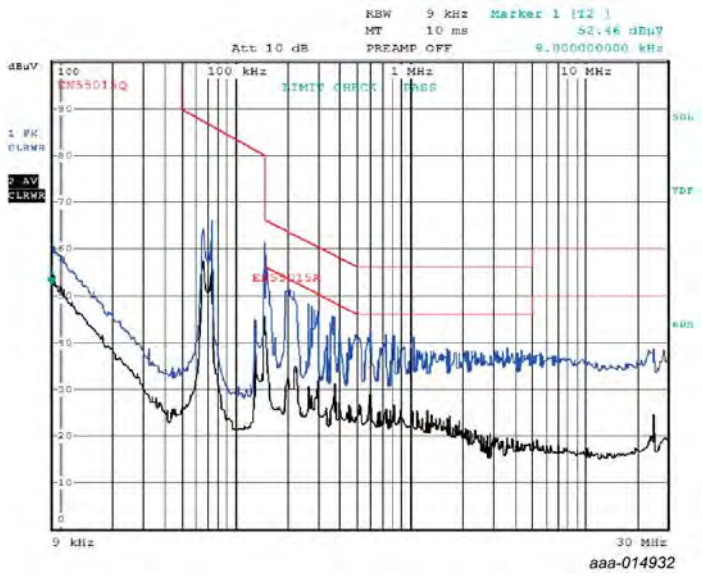

Fig 10. EMI performance

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8. Schematic

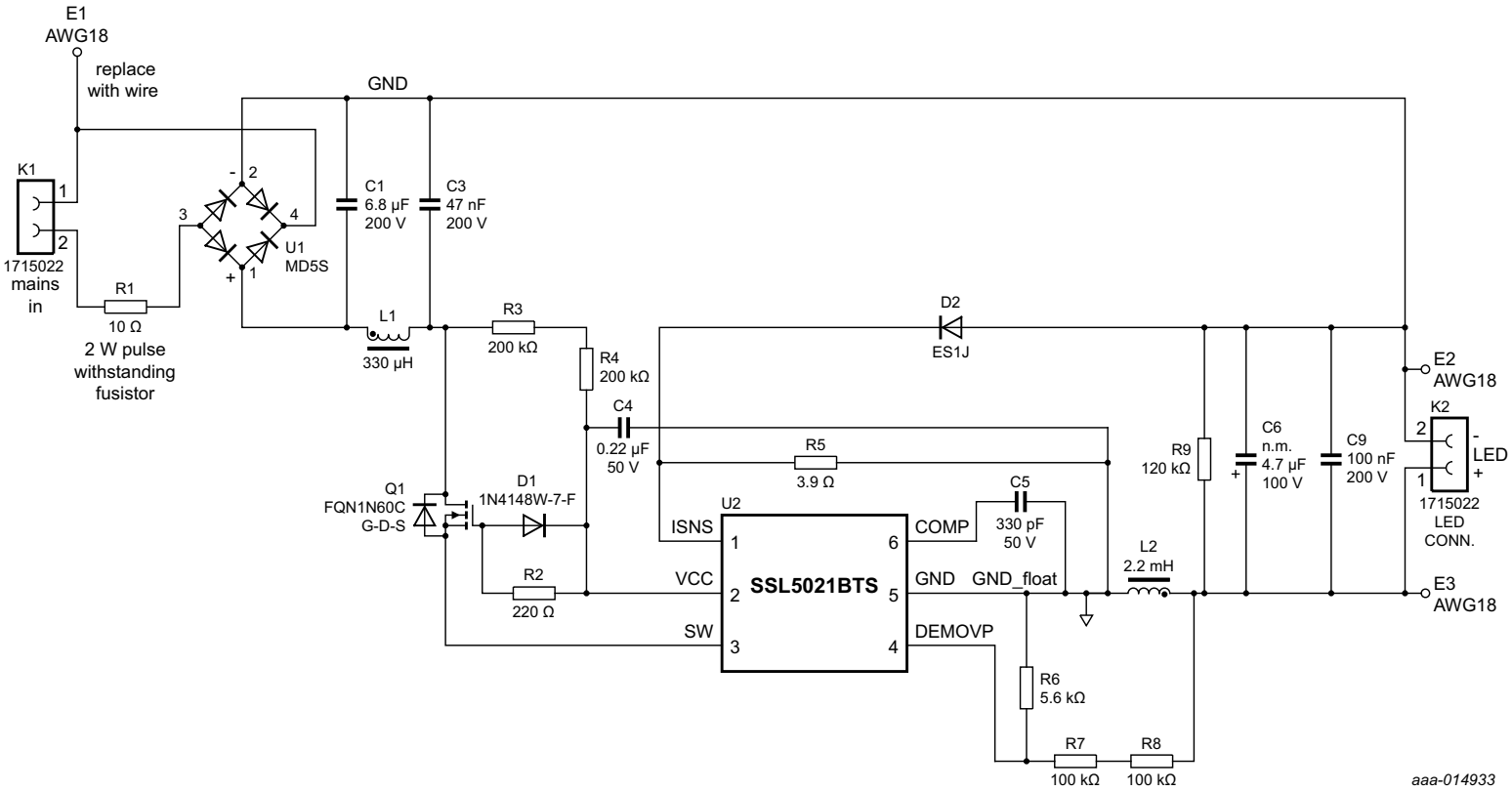

Fig 11. SSL5021BDB1205 demo board schematic

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9. Bill Of Materials (BOM)

Table 2. SSL5021BDB1205 bill of materials

Reference	Description and values	Part number	Manufacturer
C1	capacitor; 6.8 μF; 200 V	-	Rubycon
C3	capacitor; 0.047 μF; 400 V	CL21-400V-0.047μF-K	ZhongShan AIDI Electronics
C4	capacitor; 0.22 μF; 10 %; 50 V; X7R; 0603	UMK107B7224KA-TR	Taiyo Yuden
C5	capacitor; 330 pF; 630 V; 0805	C2012C0G2W330J060AA	TDK
C6	capacitor; 4.7 μF; 100 V	100ZLJM	Rubycon
C9	capacitor; 100 nF; 200 V	C1206C104K2RACTU	KEMET
D1	diode; 100 V; 300 mA	1N4148W-7-F	Diodes Incorporated
D2	diode; fast; 600 V; 1 A	MURS160-E3-52T	Vishay
K1	terminal block; 2 p.; 5.08 mm	1508060000	Weidmüller
K2	terminal block; 2 p.; 5.08 mm	20020109-H021A01LF	FCI
L1	inductor; 330 μH	RLB0812-681KL	Bourns
L2	inductor; 2.2 mH	TSL1112RA-222JR33-PF	TDK
Q1	MOSFET-N; 650 V; 0.8 A	FQN1N60C	Fairchild
R1	resistor; 22 Ω; 10 %; 2 W; EMC	EMC2-22RK	Welwyn Components
R2	resistor; 220 Ω; 1 %; 125 mW; 0603	-	-
R3; R4	resistor; 560 kΩ; 1206	-	-
R5	resistor; 4.3 Ω; 1 %; 63 mW; 1206	-	-
R6	resistor; 5.6 kΩ; 1 %; 63 mW; 0603	-	-
R7	resistor; 100 kΩ; 1 %; 250 mW; 1206	-	-
R8	resistor; 100 kΩ; 1 %; 250 mW; 1206	-	-
R9	resistor; 220 kΩ; 1 %; 250 mW; 1206	-	-
U1	bridge rectifier; 600 V; 0.8 A	B6S-G	Comchip Tech
U2	IC; SSL5021BTS; TSOP6	SSL5021BTS	NXP Semiconductors

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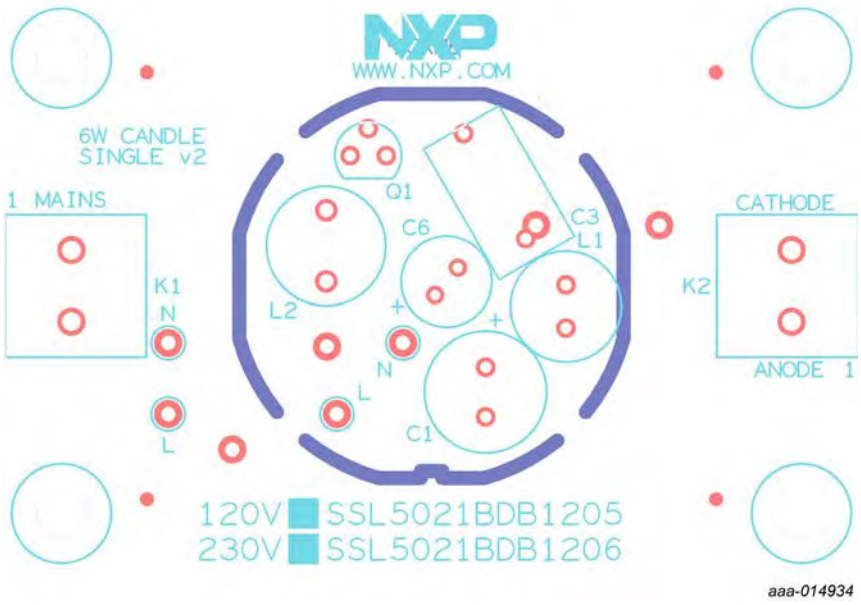
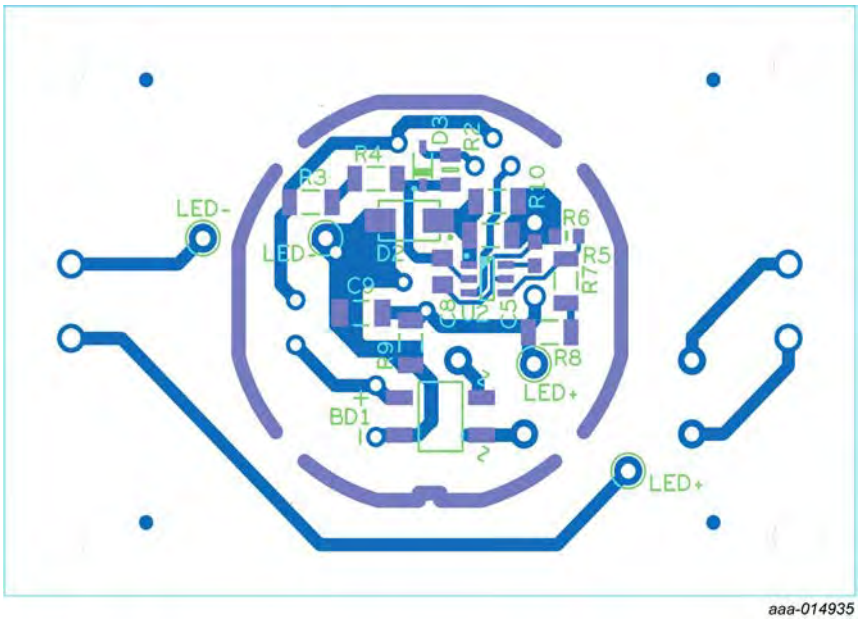
10. Board layout



a. Top view



b. Bottom view

Fig 12. SSL5021BDB1205 demo board layout

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11. Abbreviations

Table 3. Abbreviations

Acronym	Description
EMI	ElectroMagnetic Interference
LED	Light-Emitting Diode
OCP	OverCurrent Protection
OTP	OverTemperature Protection
PF	Power Factor
SSL	Solid-State Lighting

12. References

[1] SSL5021BTS data sheet — Compact low-ripple buck LED driver IC

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